

## **Section 4.10 CO<sub>2</sub> BASE EMISSION RATES AND FUEL CONSUMPTION**

### **4.10.1 Introduction**

This section details the PC, LDT and MDT gasoline and diesel carbon dioxide (CO<sub>2</sub>) base emission rates for the Unified Cycle (UC) and the Federal Test Procedure (FTP). Additionally, this memorandum details a methodology to determine fuel consumption from CO<sub>2</sub> emissions. This fuel consumption is then utilized for the determination of lead (Pb) and oxides of sulfur (SO<sub>x</sub>) emissions.

### **4.10.2 Gasoline PC, LDT and MDT CO<sub>2</sub>**

The analysis was conducted on data from surveillance and UC research test projects that included an FTP and a corresponding UC for each vehicle. The surveillance test projects included; 2S93C1, 2S95C1, and 2S97C1. Surveillance Project 2S97C1 was in progress during the analysis, so only data collected through March 11, 1999, were included. The research test projects included 2R9312, 2R9513, and 2R9811. Tests were also prescreened to determine if there was a corresponding UC for every FTP. Only baseline exhaust emission results were used for the analysis.

The data were split into three vehicle class groups, including light duty cars, light duty trucks, and medium duty vehicles. Standard vehicle class definitions were used.

Vehicles were then split into their corresponding technology and model year groups. The technology and model year groups are similar to those used in Section 4.7. Four technology groups were used including non-catalyst, carbureted, throttle body, and multi-point fuel injected. The carbureted technology group includes carbureted vehicles with a catalyst, while the non-catalyst carbureted equipped vehicles were assigned to the non-catalyst technology group.

Each technology group was further split into model year groups. The non-catalyst group contained only one model year group for vehicles less than or equal to the 1979 model year. The carbureted technology group includes model year group splits of 1975 to 1980, 1981 to 1985, and greater than or equal to 1986 model year. The throttle body technology group was split into three model year groups that included less than or equal to 1980, 1981 to 1984, and greater than or equal to 1985 model year. The fuel injection technology group was split into four model year groups that included less than or equal to 1980, 1981 to 1985, 1986 to 1992, and greater than or equal to 1993 model year.

The mean exhaust emission rates for CO<sub>2</sub> by vehicle class, technology group, and model year group, are shown in Table 4.10-1. The CO<sub>2</sub> exhaust emission rates have been determined for bags one, two and three of the FTP and for bags one and two of the UC. For each vehicle class, technology group, and model year group combination, the ratio of its CO<sub>2</sub> bag emission rates to the corresponding PC vehicle class bag emission rates were also determined. These ratios will be used to adjust the PC base emission rates (similar to

“ratio of the standards” adjustments) to be consistent with how EMFAC2000 handles hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO<sub>x</sub>). Careful examination of Table 4.10-1 shows that for several of the LDT and MDV technology/model year groupings, insufficient data were available to determine meaningful mean FTP and UC emissions. For these groups, staff used their judgment as to the most appropriate ratio. Note, each Technology Group in Table 4.10-1 has a number associated with it (in parenthesis). These numbers are used in conjunction with Table 4.10-2 to map to EMFAC2000 technology groups. The ratios are applied to each regime.

#### **4.10.3 Gasoline PC, LDT and MDT Fuel Consumption**

Fuel consumption will be determined and output in the BURDEN module only, with units of gallons consumed per day. The determination can be simplified to the following equation:

$$\text{Gallons/day} = (0.273 \cdot \text{CO}_2 \text{ TPD} + 0.429 \cdot \text{CO TPD} + 0.866 \cdot \text{HC TPD}) \cdot 375^1 \quad (4.10-1)$$

For a given calendar, class and technology group.

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<sup>1</sup>Methodology for Estimating Emissions from On-Road Motor Vehicles, Vol. VI, CARB, 1996

**Table 4.10-1. Gasoline CO<sub>2</sub> Base Exhaust Emission Rates.**

Vehicle Class	Tech Group	Model Year Group	FTP Bag 1 CO <sub>2</sub> (g/mi)	FTP Bag 2 CO <sub>2</sub> (g/mi)	FTP Bag 3 CO <sub>2</sub> (g/mi)	UC Bag 1 CO <sub>2</sub> (g/mi)	UC Bag 2 CO <sub>2</sub> (g/mi)	Ratio FTP Bag 1 CO <sub>2</sub> (g/mi)	Ratio FTP Bag 2 CO <sub>2</sub> (g/mi)	Ratio FTP Bag 3 CO <sub>2</sub> (g/mi)	Ratio UC Bag 1 CO <sub>2</sub> (g/mi)	Ratio UC Bag 2 CO <sub>2</sub> (g/mi)
PC	CB (7)	75 TO 80	565.003	548.018	492.284	848.013	524.852	1.000	1.000	1.000	1.000	1.000
PC	CB (8)	81 TO 85	386.298	392.103	336.312	597.765	363.154	1.000	1.000	1.000	1.000	1.000
PC	CB (9)	GE 86	339.043	342.227	294.719	526.110	320.738	1.000	1.000	1.000	1.000	1.000
PC	FI (1)	81 TO 85	438.143	437.199	372.958	669.262	403.968	1.000	1.000	1.000	1.000	1.000
PC	FI (2)	86 TO 92	403.625	412.167	350.430	630.219	380.286	1.000	1.000	1.000	1.000	1.000
PC	FI (3)	GE 93	382.104	390.171	330.001	613.298	359.311	1.000	1.000	1.000	1.000	1.000
PC	FI (4)	LE 80	456.434	458.658	399.755	700.804	444.563	1.000	1.000	1.000	1.000	1.000
PC	NC (10)	LE 79	531.379	533.908	470.196	775.012	500.514	1.000	1.000	1.000	1.000	1.000
PC	TB (5)	81 TO 84	490.818	506.503	426.637	778.659	454.627	1.000	1.000	1.000	1.000	1.000
PC	TB (6)	GE 85	395.071	394.943	340.523	620.788	368.565	1.000	1.000	1.000	1.000	1.000
LDT	CB (7)	75 TO 80	551.944	557.559	481.999	799.516	516.415	0.977	1.017	0.979	0.943	0.984
LDT	CB (8)	81 TO 85	475.414	482.079	417.758	715.870	450.645	1.231	1.229	1.242	1.198	1.241
LDT	CB (9)	GE 86	431.495	449.432	383.052	664.956	413.640	1.273	1.313	1.300	1.264	1.290
LDT	FI (1)	81 TO 85	395.021	386.901	353.039	598.550	392.158	0.902	0.885	0.947	0.894	0.971
LDT	FI (2)	86 TO 92	501.600	473.622	440.456	730.175	468.251	1.243	1.149	1.257	1.159	1.231
LDT	FI (3)	GE 93	491.438	484.795	424.401	751.564	463.967	1.286	1.243	1.286	1.225	1.291
LDT	FI (4)	LE 80						0.902	0.885	0.947	0.894	0.971
LDT	NC (10)	LE 79	517.370	508.583	475.965	765.559	491.444	0.974	0.953	1.012	0.988	0.982
LDT	TB (5)	81 TO 84						1.207	1.245	1.233	1.186	1.214
LDT	TB (6)	GE 85	476.997	491.805	419.732	736.015	447.597	1.207	1.245	1.233	1.186	1.214
MDV	CB (7)	75 TO 80	758.334	757.851	680.104	1027.239	663.853	1.342	1.383	1.382	1.211	1.265
MDV	CB (8)	81 TO 85	667.630	622.117	563.320	982.126	610.185	1.728	1.587	1.675	1.643	1.680
MDV	CB (9)	GE 86						1.728	1.587	1.675	1.643	1.680
MDV	FI (1)	81 TO 85						1.572	1.350	1.592	1.431	1.649
MDV	FI (2)	86 TO 92	634.404	556.395	557.818	902.014	627.115	1.572	1.350	1.592	1.431	1.649
MDV	FI (3)	GE 93	692.183	634.684	606.174	979.587	662.343	1.812	1.627	1.837	1.597	1.843
MDV	FI (4)	LE 80						1.572	1.350	1.592	1.431	1.649
MDV	NC (10)	LE 79	747.185	732.107	683.418	1082.332	704.537	1.406	1.371	1.453	1.397	1.408
MDV	TB (5)	81 TO 84						1.762	1.696	2.192	1.669	1.778
MDV	TB (6)	GE 85	695.968	669.791	746.257	1036.150	655.345	1.762	1.696	2.192	1.669	1.778

**Table 4.10-2 EMFAC2000 Technology Groups**

MAP Grp	Tech Grp	Model Yr	Description
10	1	<75	LDV no AIR
10	2	<75	LDV with AIR
10	3	75+	LDV noncatalyst
7	4	75-76	LDV OxCat with AIR
7	5	75-79	LDV OxCat no AIR
8	6	80+	LDV OxCat no AIR
7	7	77+	LDV OxCat with AIR
7	8	77-79	LDV TWC TBI/CARB
5	9	81-84	LDV TWC TBI/CARB 0.7 Nox
6	10	85+	LDV TWC TBI/CARB 0.7 Nox
4	11	77-80	LDV TWC MPFI
1	12	81-85	LDV TWC MPFI 0.7 NOx
2	13	86+	LDV TWC MPFI 0.7 NOx
5	14	81+	LDV TWC TBI/CARB 0.4 Nox
1	15	81+	LDV TWC MPFI 0.4 NOx
7	16	1980	LDV TWC TBI/CARB
6	17	93+	LDV TWC TBI/CARB .25 HC
3	18	93+	LDV TWC MPFI .25 HC
6	19	96+	LDV TWC TBI/CRB .25 OBD2
3	20	96+	LDV TWC MPFI .25HC OBD2
3	21	94-95	LDV TLEV MPFI .25HC
3	22	96+	LDV TLEV OBD2 GCL
3	23	96+	LDV LEV OBD2 GCL CBC AFC
3	24	96+	LDV ULEV OBD2 GCL CBC AFC
	25	ALL	ZEV
3	26	96+	LDT TWC MPFI OBD2 .7NOx
6	27	96+	LDT TWC TBI/CARB OBD2

#### **4.10.4 Diesel PC, LDT and MDT CO2**

MVEI7G did not have emissions estimates for CO<sub>2</sub>, nor fuel consumption, for light-duty vehicles. To create CO<sub>2</sub> BERs, 138 light-to-medium duty vehicles from CARB's Surveillance data base were analyzed. The fleet was comprised of 29 pre-1981 vehicles, 89 1981-1983 vehicles, and 20 1984-1985 vehicles. There were an insufficient number of trucks to analyze separately, so the vehicles were collapsed into one class for analysis. Although these data were collected in the early 1980s, staff believe that these results are valid for vehicles operating currently, since staff did analyze the CO<sub>2</sub> data and found no deterioration with age or odometer. Additionally, since these data pre-date the LA92/UC cycle, it is assumed that the FTP and UC rates are equivalent (Table 4.10-3).

**Table 4.10-3 - Diesel PC, LDT and MDT FTP/UC CO2 BERS (grams/mile)**

CLASS	MY	BAG 1		BAG 2		BAG 3	
		ZM	DR	ZM	DR	ZM	DR
PC DSL CO2	1965-74	392.430	0.000	455.100	0.000	375.130	0.000
	1975-79	392.430	0.000	455.100	0.000	375.130	0.000
	1980	392.430	0.000	455.100	0.000	375.130	0.000
	1981-83	381.160	0.000	437.550	0.000	364.870	0.000
	1984-85	345.720	0.000	397.840	0.000	329.880	0.000
	1986	345.720	0.000	397.840	0.000	329.880	0.000
	1987-95	345.720	0.000	397.840	0.000	329.880	0.000
	1996+	345.720	0.000	397.840	0.000	329.880	0.000
LDT DSL CO2	1965-74	392.430	0.000	455.100	0.000	375.130	0.000
	1975-79	392.430	0.000	455.100	0.000	375.130	0.000
	1980	392.430	0.000	455.100	0.000	375.130	0.000
	1981-83	381.160	0.000	437.550	0.000	364.870	0.000
	1984-85	345.720	0.000	397.840	0.000	329.880	0.000
	1986	345.720	0.000	397.840	0.000	329.880	0.000
	1987-95	345.720	0.000	397.840	0.000	329.880	0.000
	1996+	345.720	0.000	397.840	0.000	329.880	0.000
MDT DSL CO2	1965-74	392.430	0.000	455.100	0.000	375.130	0.000
	1975-79	392.430	0.000	455.100	0.000	375.130	0.000
	1980	392.430	0.000	455.100	0.000	375.130	0.000
	1981-83	381.160	0.000	437.550	0.000	364.870	0.000
	1984-85	345.720	0.000	397.840	0.000	329.880	0.000
	1986	345.720	0.000	397.840	0.000	329.880	0.000
	1987-95	345.720	0.000	397.840	0.000	329.880	0.000
	1996+	345.720	0.000	397.840	0.000	329.880	0.000

#### **4.10.5 Diesel PC, LDT and MDT Fuel Consumption**

Due to the aforementioned uncertainties associated with the diesel CO2 BERS, a simplified version of equation 4.10-1 is more:

22.2 lbs CO2/gal fuel, or<sup>2</sup>

(2) Gallons/day = (CO2 TPD)\*90

For a given calendar, class and technology group.

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<sup>2</sup> American Automobile Manufacturers Association, International Fuel Survey, Summer 1998 Los Angeles

#### **4.10.6 Pb and SOx Emissions**

The Pb and SOx emissions are a function of the lead and sulfur content of the fuel, in combination with the fuel consumption. This methodology is carried over from MVEI7G.<sup>3</sup> Tables 4.10-4 and 4.10-5 give the Pb and SOx concentrations in the fuel:

**TABLE 4.10-4 LEAD CONCENTRATION PER GALLON OF FUEL**

<b><u>CAL YEAR</u></b>	<b><u>GRAMS/GAL</u></b>
1971	2.080
1972	1.959
1973	1.904
1974	1.956
1975	1.843
1979	1.120
1980	0.831
1981	0.697
1982	0.783
1983	0.738
1984	0.660
1985	0.332
1986	0.324
1987	0.260
1988	0.083
1991	0.080
1992+	0.000

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<sup>3</sup> Methodology for Estimating Emissions from On-Road Motor Vehicles, Vol. VI, CARB, 1996

**TABLE 4.10-5 SO<sub>x</sub> CONCENTRATION IN PPM BY WEIGHT**

CAL. YEAR	STATEWIDE			SCAB		
	LEADED	UNLEADED	DIESEL	LEADED	UNLEADED	DIESEL
1975	610	380	2650	610	380	2650
1976	620	290	2340	620	290	2340
1978	350	190	3080	350	190	3080
1979	380	200	2850	380	200	2850
1980	330	210	2720	330	210	2720
1981	290	190	2800	290	190	2800
1982	310	210	2910	310	210	2910
1983	420	180	3150	420	180	3150
1984	360	250	3280	360	250	3280
1985	340	210	3000	340	210	1050
1986	400	220	3000	400	220	950
1987	400	220	3000	400	220	850
1988	400	220	3000	400	220	500
1989	400	220	3000	400	220	500
1990	400	220	3000	400	220	500
1991	151	151	3000	151	151	500
1992	151	151	3000	151	151	500
1993	151	151	500	151	151	500
1994	151	151	150	151	151	150
1995	151	151	140	151	151	130
1996- 2002	22	22	140	20	20	130
2003+	15	15	130	20	20	130